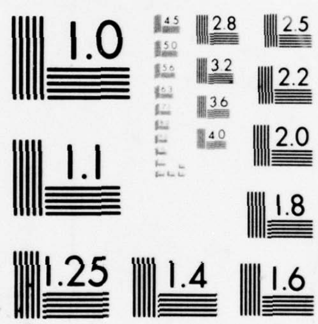
AD-A053 414 RAYTHEON CO HUNTSVILLE ALA LIFE CYCLE ANALYSIS DEPT F/G 9/1
STORAGE RELIABILITY OF MISSILE MATERIEL PROGRAM, SWITCH ANALYSI--ETC(U)
FEB 78 D F MALIK DAAK40-74-C-0853
UNCLASSIFIED LC-78-EM4 NL

1 OF 1
AD
A053414

END
DATE
FILMED
6-78
DDC



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

AD A053414

DDC FILE COPY

2
B.S.

STORAGE RELIABILITY

OF

MISSILE MATERIEL PROGRAM

U.S. ARMY
MISSILE
RESEARCH
AND
DEVELOPMENT
COMMAND

SWITCH ANALYSIS

LC-78-EM4

FEBRUARY 1978

Redstone Arsenal, Alabama 35809

PRODUCT ASSURANCE DIRECTORATE

DMI FORM 1000, 1 APR 77

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE	READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER	2. GOVT ACCESSION NO. 3. RECIPIENT'S CATALOG NUMBER
9 Final rept. Jun 74-Jan 78,	
4. TITLE (and Subtitle) 6 Storage Reliability of Missile Materiel Program, Switch Analysis.	5. TYPE OF REPORT & PERIOD COVERED Final, June 1974 to Jan. 1978
	6. PERFORMING ORG. REPORT NUMBER 14 LC-78-EM4
7. AUTHOR(s) 10 Dennis F. Malik	8. CONTRACT OR GRANT NUMBER(s) 15 DAAK40-74-C-0853
9. PERFORMING ORGANIZATION NAME AND ADDRESS Raytheon Company, Equipment Division 3322 S. Memorial Parkway Huntsville, AL 35801	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS	11 12. REPORT DATE Feb[redacted]78 12
	13. NUMBER OF PAGES 25 28 p.
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)	15. SECURITY CLASS. (of this report) Unclassified
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Reliability, Storage, Missile Materiel, Failure Rates, Failure Mechanisms, Operation, Switches

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report documents findings on the non-operating reliability of switches. Recommendations include care to avoid particulate contamination and inclusion of oxygen in the fill gas for enclosed designs. This information is part of a research program being conducted by the U. S. Army Missile R&D Command, Redstone Arsenal, Alabama. The objective of this program is the development of non-operating (storage) reliability prediction and assurance techniques for missile materiel. This report updates and replaces report

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE 391 619

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

20. Abstract (cont'd)

LC-76-EM4 dated May 1976.

STORAGE RELIABILITY
OF
MISSILE MATERIEL PROGRAM

SWITCH ANALYSIS

LC-78-EM4 FEBRUARY 1978

Prepared by: D. F. Malik

PROJECT DIRECTOR

C. R. PROVENCE

PRODUCT ASSURANCE DIRECTORATE

HEADQUARTERS
U. S. ARMY MISSILE R&D COMMAND
REDSTONE ARSENAL, ALABAMA

IN COMPLIANCE WITH
CONTRACT NO. DAAK40-74-C-0853
DATED 4 JUNE 1974
DATA ITEM SEQUENCE NO. 3

RAYTHEON COMPANY
EQUIPMENT DIVISION

LIFE CYCLE ANALYSIS DEPARTMENT
HUNTSVILLE, ALABAMA

ABSTRACT

This report documents findings on the non-operating reliability of switches. Long term non-operating data has been analyzed and reliability predictions have been developed for switches.

This report is a result of a program whose objective is the development of non-operating (storage) reliability prediction and assurance techniques for missile materiel. The analysis results will be used by U. S. Army personnel and contractors in evaluating current missile programs and in the design of future missile systems.

The storage reliability research program consists of a country wide data survey and collection effort, accelerated testing, special test programs and development of a non-operating reliability data bank at the U. S. Army Missile R&D Command, Redstone Arsenal, Alabama. The Army plans a continuing effort to maintain the data bank and analysis reports.

This report is one of several issued on electromechanical devices and other missile materiel. For more information contact:

Commander
U. S. Army Missile Research & Development Command
ATTN: DRDMI-QS, Mr. C. R. Provence
Building 4500
Redstone Arsenal, AL 35809
Autovon 746-3235
or (205) 876-3235

TABLE OF CONTENTS

TABLES

SECTION 1
INTRODUCTION

Materiel in the Army inventory must be designed, manufactured and packaged to withstand long periods of storage and "launch ready" non-activated or dormant time. In addition to the stress of temperature soaks and aging, they must often endure the abuse of frequent transportation and handling and the climatic extremes of the forward area battlefield environment. These requirements generate the need for special design, manufacturing and packaging product assurance data and procedures. The U. S. Army Missile R&D Command has initiated a research program to provide the needed data and procedures.

This report updates report LC-76-EM4, dated May 1976, and covers findings from the research program on switches. The program approach on these devices has included literature and user surveys, data bank analyses, data collection from various military systems and special testing programs.

SECTION 2
SUMMARY

Storage data for switches was collected showing 65 failures in 698.6 million part hours. Predicted non-operating failure rates for various switch types are given in Table 2-1. Also included is the 90% confidence limit. The true failure rate should lie below this limit with 90% confidence. For switches showing failures, a range of failure rates from 29.4 to 1130 fits was observed.

A comparison to operational failure rates is given. Operational/storage failure rate ratios from 9 to 147 are found in the ground environment.

No recommendation is made as to storage environment. If the contacts are in a sealed enclosure, the fill gas should include oxygen. Particular care should be taken to avoid particulate contamination in manufacture.

TABLE 2-1. SWITCHES NON-OPERATING FAILURE RATES

TYPE	FAILURE RATE IN FITS*	90% CONFIDENCE LIMIT
General	82.8	125.3
Toggle/Pushbutton	26.0	101.1
Pressure	54.2	108.4
Thermal	17.1	66.6
Sensitive	82.6	125.3
Stepping	400.	1064.
Manual Rotary S&A	82.6	125.3
Solenoid	109.3	172.7
Motor Driven S&A	138.2	218.5
Inertial	66.4	98.7

*Failures per billion hours

SECTION 3

PRINCIPLES OF OPERATION

The processes operative at the switch contacts are identical to those in relays. In particular, mention should be made of the desirability of snap action, i.e., positive spring force on the contacts when closed, and a positive separation distance when open; the possibility of bridging and arcing on opening; and the possibility of welding on closing. These phenomena have been discussed at length in a previous report in this series, Reference 4. Switches are sometimes classified by the actuating force (inertial, pressure, push, etc.) or by mechanical features of the mechanism (toggle, stepping, rotary, etc.). Where classification is available, it appears in the comment column of the tables in this report.

SECTION 4
DATA ANALYSIS

4.1 Data Description

Switch non-operating data was obtained from four sources and four missile programs. The data represents 698.6 million switch non-operating hours with 65 failures reported. The data broken out by switch type is presented in Table 4-1. For those entries showing failures, the failure rate ranges from 29.4 fits (failures per billion hours) to 1130 fits.

Each data source is described in detail below.

4.1.1 Source A Data

Source A represents a reliability study performed under contract to RADC in 1974. This source identified the type and quality grades for the devices, however, it provided no information regarding storage conditions or individual programs. Data was available on toggle/pushbutton, pressure, sensitive, stepping, and inertial switches as well as a "general" category of switches. Failures were reported for pressure switches (4 failures in 48.3 million hours); stepping switches (2 failures in 5 million hours), and inertial switches (9 failures in 137.1 million hours). No data was given on failure mode or mechanisms.

4.1.2 Source C Data

Source C represents a reliability study performed under contract to RADC in 1968. No environments were provided. Data was available on toggle/pushbutton, pressure, thermostatic, sensitive and inertial switches as well as a "general" category of switches. Failures were reported for "general" switches (11 failures in 89.5 million hours), pressure switches (10 failures in 31 million hours), and inertial switches (6 failures in 25.3 million hours). No failure modes or mechanisms were provided.

4.1.3 Source P Data

Source P represents a special aging and surviellance program. Devices are stored in a controlled environment. Data was available on three types of inertial switches.

The first data entry in Table 4-1 represents a 3-G switch. Forty switches were tested having an average age of 64 months (the oldest switch was 66 months). No failures were recorded on this switch.

The second data entry for source P in Table 4-1 represents a safety inertial switch. Forty switches were also tested having an average age of 61 months (the oldest switch was 67 months). Two failures were recorded with the following causes given: 1) Corrosion on shaft - age 60 months; 2) Escapement mechanism slippage - age 56 months. Six other failures were recorded but they were not classified as catastrophic. Four of these were classified as failure cause unknown (ages: 35, 37, 56 and 64 months) and the switches tested satisfactorily in later tests. The fifth failure was classified as "improper clearance between pinion gear and timing weight (age 60 months) and the sixth failure as "foreign particle between pinion gear and timing weight" (age 51 months). Both switches tested satisfactorily at a later test.

The third data entry for source P in Table 4-1 represents a magnetic inertial switch. Twenty three switches were tested having an average age of 32 months (the oldest switch was 33 months). No failures were recorded on this switch.

4.1.4 Source R Data

Source R data represents a safe and arm (S&A) switch as analyzed in report LC-76-OR2. The inertial S&A data represents two missile programs. For these switches acceleration of the missile causes a g-weight to move which causes a rotary switch and a blocking rotor to rotate. Rotation of the blocking rotor arms the igniter mechanically by opening the ignition ports between the electrical squibs and the ignition pellets. The igniter is electrically armed by the rotation of the rotary switch, closing the igniter electric circuit.

The first inertial S&A program tested 21 switches with ages ranging from 45 to 91 months for an average age of 65 months. No failures were recorded on these switches.

TABLE 4-1. SWITCH NON-OPERATING DATA

SWITCH TYPE	SOURCE	NO. OF DEVICES	NON-OP. HRS. IN MILLIONS	NO. OF FAILURES	FAILURE RATE IN FITS
General	A	-	43.328	0	(<23.1)
	C	-	6.658	0	(<150.2)
	C	-	.1665	0	(<6006.)
	C	-	3.095	0	(<323.1)
	C	-	.2418	0	(<4136.)
	C	-	38.688	4	103.4
	C	-	37.2	6	161.3
	C	-	3.442	1	290.5
(TOTAL GENERAL			132.819	11	82.8)
Toggle/ Pushbutton	A	-	.603	0	(<1658.)
	A	-	1.01	0	(<990.)
	C	-	.0555	0	(<18018.)
	C	-	.3699	0	(<2703.)
	C	-	.1775	0	(<5634.)
	C	-	1.274	0	(<785.)
	Missile E-1	874	12.76	0	(<78.4)
	Missile F	240	5.256	0	(<190.)
	Missile H	1071	17.0	1	58.8
(TOTAL TOGGLE/PUSHBUTTON			38.5059	1	26.0)
Pressure	A	-	48.3	4	82.8
	C	-	31.001	10	322.6
	Missile E-1	1748	25.52	0	(<39.2)
(TOTAL PRESSURE			104.821	14	133.6)
Thermostatic	C	-	3.699	0	(<270.3)
	C	-	.0663	0	(<15083.)
	C	-	.111	0	(<9001.)
	Missile H	2142	34.0	1	29.4
	Missile I	2070	20.59	0	(<48.6)
(TOTAL THERMOSTATIC			58.4663	1	17.1)
Sensitive	A	-	1.644	0	(<608.3)
	C	-	.3699	0	(<2703.)
(TOTAL SENSITIVE			2.0139	0	(<496.5)
Stepping	A	-	5.00	2	400.
Manual Rotary S&A	R	101	3.574	0	(<280.)

TABLE 4-1. SWITCH NON-OPERATING DATA (cont'd)

SWITCH TYPE	SOURCE	NO. OF DEVICES	NON-OP. HRS. IN MILLIONS	NO. OF FAILURES	FAILURE RATE IN FITS
Solenoid	Missile I	8280	82.36	9	109.3
Motor Driven (S&A)	R	2016	65.104	9	138.2
Inertial	A	-	137.1	9	65.6
	C	-	25.337	6	236.8
	P	40	1.87	0	(<535.)
	P	40	1.77	2	1130.
	P	23	.54	0	(<1852.)
	R	21	.992	0	(<1008.)
	R	74	5.007	1	199.7
	Missile E-1	874	12.76	0	(<78.4)
	Missile I	2070	20.59	0	(<48.6)
(TOTAL INERTIAL			205.966	18	87.4)

The second inertial switch program tested 74 switches with ages ranging from 40 to 138 months for an average age of 93 months. One catastrophic failure was recorded where an improperly manufactured cover plate caused the arming socket to be improperly placed and interference between the rotary switch and the electrical contacts prevented the switch shaft from rotating. These switches were supposedly tested when placed into the inventory. Ten other failures were recorded as specification failures. Six failed to arm within the maximum specified time and four armed sooner than the minimum specified time. These specification failures were marginal and would not have affected the mission. Causes for two failures were identified: 1) misaligned gear train caused by two screws on the g-weight shafts being loose; and 2) improperly manufactured cover plate.

The manual rotary S&A data represents one missile program. The program tested 101 switches ranging in age from 9 to 75 months with an average age of 48 months. No failures were recorded.

The motor driven S&A data represents one missile program. The program tested 2017 switches ranging in age from 12 months to 96 months with an average age of 44 months. Nine failures were recorded as fails to arm or disarm. Thirty five failures were reported in which arming times exceeded minimum mission requirements. Note that this program had very stringent requirements on arming time. Forty nine failures were reported in which arming or safing times exceeded original acceptance specifications, however did meet mission requirements.

No detailed failure mechanism analysis was performed, however, age sensitive items were noted. These included swelling, cracking and general materiel degradation of O-rings, packing and insulators. Corrosion of bearings, contacts, switch ports, gear assemblies and motor armature were also postulated. Load relaxation of helical compression springs and bonding of friction plate clutch assembly were also noted.

Eighty percent of the failures involved long arming times. An age trend analysis was performed on the parametric data. The analysis indicated an average increase in arming time of 13 percent per year.

4.1.5 Missile E-1 Data

Missile E-1 data consists of 874 missiles stored for 20 months. The missiles were stored in containers exposed to external environmental conditions in the northeast U. S. They were also transported once from coast to coast. Data was available on toggle, pressure and inertial switches. No failures were recorded.

4.1.6 Missile F Data

Missile F data consists of 120 missiles, 60 of which were stored for one year and 60 for two years. The missiles in storage containers experienced the following environments: 30 missiles stored outside in the Arctic on wooden racks with canvas covers; 30 missiles stored outside in the southeast desert under open sided metal roof sheds; 30 missiles stored outside in the canal zone under open sided metal roof sheds; and 30 missiles stored in the southeast U. S. in bunkers. Data was available on toggle switches. No failures were reported.

4.1.7 Missile H Data

Missile H data represents field data from a recent army missile program fielded in the 1970's. The major item in which the devices were assembled was subjected to operating times at high and low temperatures, shock and vibration. The missiles were transported overseas and stored for various lengths of time. No tests were run until the missiles were removed from storage and returned to the states. Storage durations varied from 6 months to 6 years with an average time of 1.8 years. Storage environments included cannister time in a controlled environment, cannister time subject to outside elements and missile time on pallets and on launchers. A number of samples were also run through road tests under field conditions. Data was available on pushbutton and thermostatic switches. The one failure of a pushbutton switch was recorded as a bent leaf

spring contact. No failure analysis was available on the thermal switch.

4.1.8 Missile I Data

Missile I data consists of 2,070 missiles stored for periods from 1 months to 40 months for an average storage period of 14 months. Approximately 80 percent of the missiles were stored in U. S. depots while the remainder were stored at various bases around the country. Data was available on thermostatic, inertial and solenoid switches. No failures were reported for the thermostatic or inertial switches. Nine failures were recorded on the solenoid switches. No failure analysis was available on these switches, however the main failure mode was "intermittent."

4.2 Data Evaluation

The data from the various sources were combined by device type as shown in Table 4-1. A test of significance (see Appendix A) was performed to test whether there was any significant differences in the data entries under each device type. Two device types, pressure switches and inertial switches, indicated a significant difference within the data entries.

For pressure switches the source with the most failures, source C, also represents the oldest data (1968 study). Therefore, this data entry was removed. The remaining entries include 4 failures in approximately 74 million hours with a failure rate of 54.2 fits.

For inertial switches, the same data entry (Souce C) was removed and the entries retested. The test indicated no significant differences within the remaining entries. These entries include 12 failures in approximately 181 million hours with a failure rate of 66.4 fits.

Two device types, sensitive and manual rotary S&A, indicated no failures. It is recommended that the "general" category failure rate be used until further data is collected on these devices. The pooled switch data and failure rates are

shown in Table 4-2. The right hand column in Table 4-2 gives the 90% confidence one-sided limit on the failure rate. The true failure rate should lie below this limit with 90% confidence.

TABLE 4-2. POOLED SWITCH NON-OPERATING DATA

TYPE	NON-OP. HRS. IN MILLIONS	NO. OF FAILURES	FAILURE RATE IN FITS	90% CONFIDENCE ONE-SIDED FAILURE RATE
General	132.819	11	82.8	125.3
Toggle/ Pushbutton	38.506	1	26.0	101.1
Pressure	73.82	4	54.2	108.4
Thermostatic	58.466	1	17.1	66.6
Sensitive			*	*
Stepping	5.00	2	400.	1064.
Manual Rotary S&A			*	*
Solenoid	82.36	9	109.3	172.7
Motor Driven S&A	65.104	9	138.2	218.5
Inertial	180.629	12	66.4	98.7

*Use "general" failure rate.

4.3 Operational/Non-Operational Reliability Comparisons

Operational failure rate data for switches was extracted from report RADC-TR-74-268, Revision of RADC Nonelectronic Reliability Notebook, D. F. Cottrell, et al, Martin Marietta Aerospace, dated October 1974. This data is shown in Tables 4-3 through 4-10 and compared with the non-operating failure rate prediction. Comparing the common environment (ground), the non-operating to operating ratio ranges from 1:9 for the general category of switches to 1:147 for thermostatic switches.

TABLE 4-3. OPERATIONAL/NON-OPERATIONAL RELIABILITY COMPARISON - SWITCHES, GENERAL

	PART HRS. (10^6)	NO. OF FAILURES	FAILURE RATE IN FITS	$\lambda_{op}/\lambda_{no}$
Environment				
Non-Operating				
Ground, Fixed	132.819	11	82.8	-
Operating				
Satellite	7.880	4	507.6	6.
Ground	1.347	0	(<742.4)	9.
Airborne	10.279	1100	107014.	1292.
Helicopter	3.528	348	98639.	1191.
Submarine	3.952	2	506.1	6.

TABLE 4-4. OPERATIONAL/NON-OPERATIONAL RELIABILITY COMPARISON - SWITCHES, PRESSURE

	PART HRS. (10^6)	NO. OF FAILURES	FAILURE RATE IN FITS	$\lambda_{op}/\lambda_{no}$
Environment				
Non-Operating				
Ground, Fixed	73.82	4	54.2	-
Operating				
Ground	47.741	100	2095.	39
Ground, Mobile	17.184	105	6110.	113
Airborne	34.425	1929	56035.	1034
Helicopter	1.047	348	332378.	6132
Submarine	.613	4	6525.	120
Shipboard	.798	18	22556.	416

TABLE 4-5. OPERATIONAL/NON-OPERATIONAL RELIABILITY COMPARISON - SWITCHES, PUSHBUTTON

	PART HRS. (10^6)	NO. OF FAILURES	FAILURE RATE IN FITS	$\lambda_{op}/\lambda_{no}$
Environment				
Non-Operating				
Ground, Fixed	38.506	1	26.0	-
Operating				
Ground	22.184	6	270.5	10.
Airborne	3.624	101	27870.	1072.
Helicopter	1.286	0	(<777.6)	30.
Submarine	89.879	7	77.9	3.
Shipboard	120.156	55	457.7	18.

TABLE 4-6. OPERATIONAL/NON-OPERATIONAL RELIABILITY COMPARISON - SWITCHES, ROTARY

	PART HRS. (10^6)	NO. OF FAILURES	FAILURE RATE IN FITS	$\lambda_{op}/\lambda_{no}$
Environment				
Non-Operating				
Ground, Fixed	-	-	82.8	-
Operating				
Satellite	2.391	1	418.2	5
Ground	36.108	48	1329.	16
Airborne	14.749	261	17696.	214
Helicopter	.092	2	21739.	263
Submarine	20.204	32	1584.	19
Shipboard	52.097	80	1536.	19

TABLE 4-7. OPERATIONAL/NON-OPERATIONAL RELIABILITY COMPARISON - SWITCHES, SENSITIVE

	PART HRS. (10^6)	NO. OF FAILURES	FAILURE RATE IN FITS	$\lambda_{op}/\lambda_{no}$
Environment				
Non-Operating				
Ground, Fixed	-	-	82.8	-
Operating				
Ground	11.472	13	1133.	14.
Airborne	12.560	184	14650.	177.
Helicopter	.610	3	4918.	59.
Submarine	45.927	51	1110.	13.
Missile	.008	2	250000.	3019.

TABLE 4-8. OPERATIONAL/NON-OPERATIONAL RELIABILITY COMPARISON - SWITCHES, STEPPING

	PART HRS. (10^6)	NO. OF FAILURES	FAILURE RATE IN FITS	$\lambda_{op}/\lambda_{no}$
Environment				
Non-Operating				
Ground, Fixed	5.00	2	400.	-
Operating				
Submarine	.234	5	21368.	53.

TABLE 4-9. OPERATIONAL/NON-OPERATIONAL RELIABILITY COMPARISON - SWITCHES, THERMOSTATIC

	PART HRS. (10^6)	NO. OF FAILURES	FAILURE RATE IN FITS	$\lambda_{op}/\lambda_{no}$
Environment				
Non-Operating				
Ground, Fixed	58.466	1	17.1	-
Operating				
Ground	4.381	11	2511.	147.
Airborne	6.733	44	6535.	382.
Helicopter	.218	9	41284.	2414.
Submarine	1.838	7	3808.	223.
Shipboard	45.767	29	633.6	37.

TABLE 4-10. OPERATIONAL/NON-OPERATIONAL RELIABILITY COMPARISON - SWITCHES, TOGGLE

	PART HRS. (10^6)	NO. OF FAILURES	FAILURE RATE IN FITS	$\lambda_{op}/\lambda_{no}$
Environment				
Non-Operating				
Ground, Fixed	38.506	1	26.0	-
Operating				
Ground	237.545	135	568.3	22.
Ground,Mobile	.359	1	2786.	107.
Airborne	35.446	255	7194.	277.
Helicopter	.430	8	18605.	716.
Shipboard	141.438	67	474.	18.

4.4 Failure Modes

Table 4-11 summarizes the failure modes and mechanisms that were identified in the non-operating data. They include corrosion of contacts and other metal surfaces; load relaxation of springs; aging of O-rings, packing, etc., as long term mechanisms. Other mechanisms appear to be manufacture related. The majority of these devices were thoroughly tested before being placed into storage. The manufacture related defects therefore must be marginal problems which escape these tests and are sufficiently stressed in the storage environments to result in failures.

Table 4-12 summarizes failure modes of switches in operational environments. This table, taken from data source C, shows the distribution of failures in switches, for those failures which could be identified quantitatively.

TABLE 4-11. REPORTED FAILURE MODES & MECHANISMS IN STORAGE

SWITCH TYPE	FAILURE MODES & MECHANISMS
Inertial	Corrosion
Inertial	Mechanism slippage
Inertial	Foreign particle
Inertial	Improper clearance
Inertial	Improperly manufactured cover plate - 2
Inertial	Misaligned gear train
Motor Driven	Swelling, cracking & general materiel degradation of O-rings, packing & insulators
Motor Driven	Corrosion of bearings, contacts, switch parts, gear assemblies & motor armature
Motor Driven	Load relaxation of helical compression springs
Motor Driven	Bonding of friction plate clutch assembly
Pushbutton	Bent leaf spring contact

TABLE 4-12. OPERATIONAL FAILURE DISTRIBUTION FOR SWITCHES

Failure Mode	Number of Failures	Percentage
Contamination	5	1
Failed to operate	9	1
Improper adjustment	16	2
Improper operation	16	2
Intermittent operation	72	10
Internal part failure	0	0
Leaking	8	1
Mechanical damage	127	17
Mechanical interference	56	7
Missing or wrong part	0	0
Slow or sluggish operation	0	0
Weak or aging effect	5	1
Arcing	0	0
Drift/unstable/erratic	42	6
Defective contacts	12	2
Open	58	8
Shorted	30	4
Squib failed to fire	79	10
Voltage out of spec	29	4
Dielectric, humidity	0	0
Unknown	190	25
TOTAL	754	

PRECEDING PAGE NOT FILMED BLANK

BIBLIOGRAPHY

1. "Effects of Dormancy on Nonelectronic Components and Materials," RADC-TR-73-269, Martin Marietta Aerospace, Oct. 1974.

2. "Reliability Data from In-Flight Spacecraft; 1958-1970" AD 889943, E. E. Bean and C. E. Bloomquist, 30 Nov. 1971.

3. "Data Collection for Nonelectronic Reliability Handbook," RADC-TR-68-114, W. Yurkowsky, Hughes Aircraft, June 1968.

4. "Relay Analysis," R. Cordray, LC-76-EM3, Raytheon Company, Huntsville, AL.

5. Unpublished data from current missile Program A.

6. Unpublished data from current missile Program B.

7. "Reliability Prediction of Electronic Equipment," MIL-HDBK-217B, 20 Sept. 74.

8. "Summaries of Failure Rate Date," v. 1, Government-Industry Data Exchange Program, Jan. 1974.

9. "Revision of RADC Nonelectronic Reliability Notebook," (RADC-TR-69-458), Section 2, Donald F. Cottrell, et al, Martin Marietta Aerospace, Oct. 1974, AD/A-002 152.

APPENDIX A

TEST OF SIGNIFICANCE OF DIFFERENCES IN FAILURE RATES (MORE THAN TWO POPULATIONS)

The storage reliability data is obtained from numerous sources. A detailed qualitative analysis is performed on the data to classify devices, environments, uses, quality levels, failures modes & mechanisms, and so on. Once the data sets are grouped according to these analyses, it is still not certain whether grouped sets of failure data are in truth from the same statistical population. It is possible that the failure rate characteristics of identical devices from the same manufacturers, with the same application, use environment, and so on, are not from the same population in terms of reliability -- possibly due to some problem on a production line for a certain lot or other factor.

Therefore a statistical test is performed to determine if the different data sets could be from the same statistical population.

The technique used is for more than two data sets and is taken from "Statistical Methods for Research Workers," R. A. Fisher, 13th edition, Hufner, 1963, pages 99-101.

The techniques assumes that the underlying failure distributions each have the same constant failure rate (λ). Therefore, the probability of a number of failures for each population can be represented by the Poisson distribution.

A single failure rate is calculated based on the pooled data sets being tested.

$$\lambda = \frac{\sum_{i=1}^{N} f_i}{\sum_{i=1}^{N} T_i}$$

where λ = Mean failure rate for all data sets

f_i = the number of failures in data set i

T_i = the total storage hours in data set i

n = the number of data sets being tested

The expected number of failures and the difference between the expected number of failures and actual failures is calculated for each data set based on the pooled data:

$$M_i = \lambda T_i$$

$$d_i = |f_i - m_i|$$

where

M_i = expected number of failures for data set: (based on the pooled data sets)

d_i = absolute value of the differences between the expected number of failures and the actual failures for data set i.

Next, lower and upper limits are calculated for the Poisson distribution:

$$U_i = [M_i + d_i] \text{ (if } U_i = f_i\text{, set } U_i = f_i - 1)$$

$$L_i = \langle M_i - d_i \rangle \text{ (if } L_i = f_i\text{, set } L_i = f_i + 1)$$

$$\text{(if } L_i < 0\text{, set } L_i = 0)$$

U_i = upper limit for data set i

L_i = lower limit for data set i

[ ] = rounded down to integer value

< > = rounded up to integer value

The probability that f_i failures would occur in data set i given the population failure rate is λ, is expressed by the Poisson distribution:

$$P_i = 1 - \sum_{j=L_i}^{U_i} P_{ij}$$

$$= 1 - \sum_{j=L_i}^{U_i} e^{-M_i} \frac{M_i^{\,j}}{j!}$$

The individual probabilities, P_i, are the significance probabilities for the individual distributions. It is required to test whether the ensemble of P_i taken together represents an improbable configuration under the null hypothesis which is that the underlying distributions have the same constant failure rate (λ).

The test is done as follows:

$$C_i = -2 \ln P_i$$

$$C = \sum_{i=1}^{n} C_i$$

Find Cr for $\alpha = .05$ (5% level of significance) and 2n degrees of freedom from the tables of chi square.

If C>Cr reject the null hypothesis (that all of the populations have the same failure rate.)

If the null hypothesis is not rejected, the data sets can be pooled and the common failure rate λ used.

If the null hypothesis is rejected, engineering and statistical analysis is required to remove data sets from the pooled data until the null hypothesis is not rejected.

EXAMPLE 1:

DATA SET	T_i	F_i	M_i	d_i	U_i	L_i	P_i	C_i
1	587.4	19	12.9	6.1	18	7	.0936	4.74
2	144.1	0	3.2	3.2	3	1	.0849	4.93
3	65.6	1	1.4	.4	2	2	1.000	0
4	95.8	1	2.1	1.1	3	2	.5406	1.23
5	128.	3	2.8	.2	3	3	1.000	0
6	281.	15	6.2	8.8	14	0	.0018	12.60
7	78.6	2	1.7	.3	1	1	1.000	0
8	484.8	0	10.7	10.7	21	1	.0016	12.93
	1865.6	41					$\Sigma C_i =$	36.43

pooled - λ = 21.98 fits

C = 36.43

2n degrees of freedom = 16

(from chi-square dist. at $\alpha = .05$) Cr = 26.30

Since C>Cr ---- the null hypothesis, that all of the populations have the same failure rate, is rejected.

EXAMPLE 2:

DATA SET	T_i	f_i	M_i	d_i	U_i	L_i	P_i	C_i
1	587.4	19	19.5	.5	20	20	1.0	0
2	65.6	1	2.2	1.2	3	2	.536	1.2
3	95.8	1	3.2	2.2	5	2	.277	2.57
4	128.	3	4.2	1.2	5	4	.641	.89
5	281.	15	9.3	5.7	14	4	.070	5.33
6	78.6	2	2.6	.6	3	3	1.02	.0
	1236.4	41						9.99

Pooled λ = 33.16 fits

C = 9.99

2n degrees of freedom = 12

Cr = 21.03

C<Cr - accept null hypothesis --

All data sets have the same failure rate (λ = 33.16 fits).